Human Physiology, Performance, Protection & Operations Laboratory (H-3PO)

Zachary Wusk, M.S., HHPC/KBR

Patrick Estep, M.S., HHPC/GeoControl Systems

Jeff Somers, Karina Marshall-Goebel, Renita Fincke, H3PO, NASA

*This work was funded by NASA EVA and Human Surface Mobility Program and NASA Mars Campaign Development-Exploration Capabilities

Photo & video credit: NASA

My Background

- VT Mechanical Engineering ’21 B.S.
  - Biomedical Minor
- VT/WF Biomedical Engineering ‘22 M.S.
- VT Helmet Lab

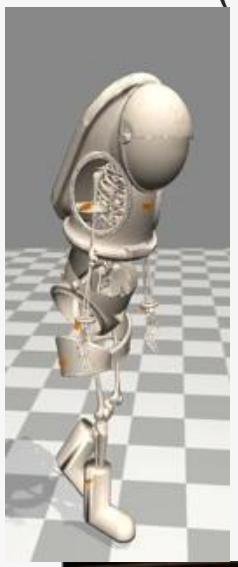
- KBR Human Performance Engineer in H-3PO
  - NASA Johnson Space Center
  - Houston, TX
  - Started July 2022

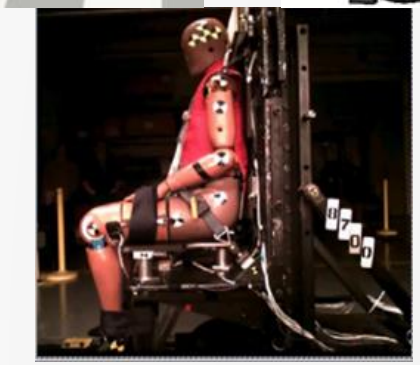
H-3PO

- Human Physiology, Performance, Protection, and Operations Laboratory
- Focused on the “human” aspects of space flight and exploration
  - Identifying risks
  - Understanding and monitoring physiological changes
  - Evaluating and improving health and performance
- Multi-disciplinary team of engineers, physiologists, physicians, etc.
- Varied backgrounds across all facets of human health and performance, including:
    - Space physiology
    - Astronautics/aeronautics
    - Kinesiology/Injury biomechanics
    - Exercise science
    - Data science/computational modeling
    - Virtual and hybrid-reality technologies
- Often collaborate with the Anthropometry and Biomechanics Facility (ABF), Behavioral Health and Performance (BHP), and other labs on joint projects

Technical Areas of H-3PO

Applied Injury Biomechanics (AIB)





Exercise Performance and Countermeasures (EPC)

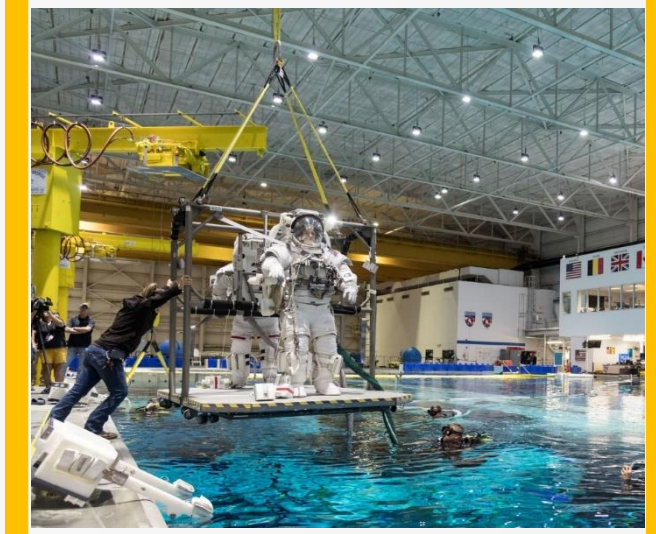
Space Suits & Exploration Operations (SSEO)

SSEO Overview

- Program Integration & Support
  - Coordinate and integrate across multidisciplinary subject matter experts to support current mission operations, commercial crew programs, and future exploration operations
    - Review and/or development of programmatic requirements and recommendations
    - Identification of risks or gaps across programs and development plans to address them
- Technology & Simulation Development
  - Development of content to conduct EVA simulations and physiologic + functional models
- Research & Testing
  - Execute engineering evaluations and research-driven testing across multiple analog environments

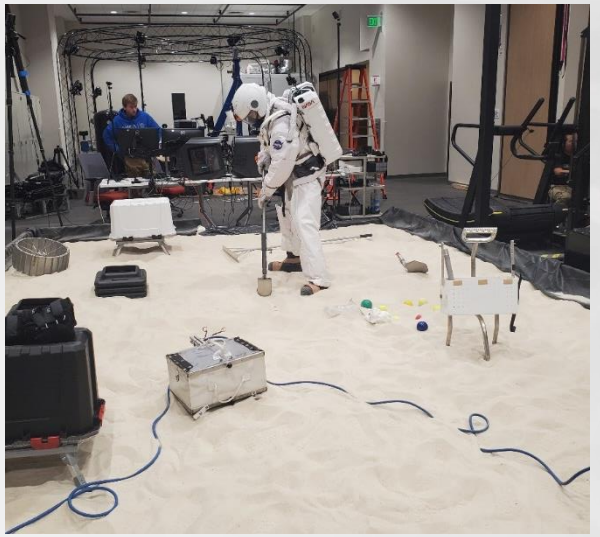
Test Facilities

Neutral Buoyancy Lab (NBL)



Active Response Gravity Offload System (ARGOS)

Hybrid Reality Spaces



Field Testing

Test Facilities: Neutral Buoyancy Lab (NBL)

- Pro: Great for experiencing reduced gravity, high fidelity simulations
- Con: Water drag, lots of preparation, joint test runs

- 202 ft x 102 ft x 40 ft, 6 million gallons of water

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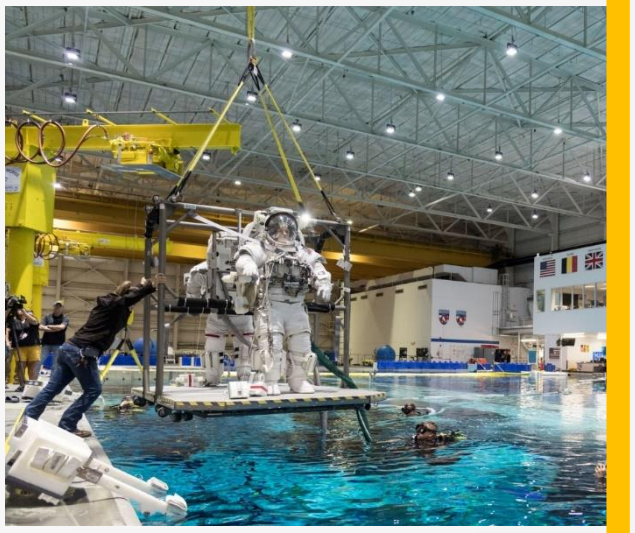

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- Pro: Keeps momentum in movements, EVA tasks, communication/interaction
- Con: Extremities still in 1g, limited space

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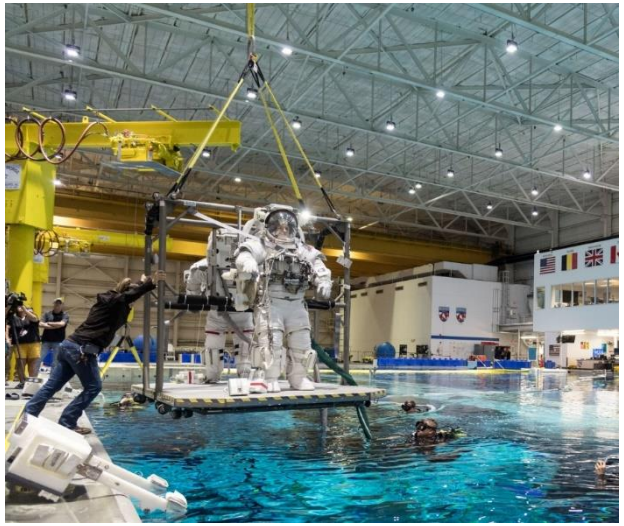

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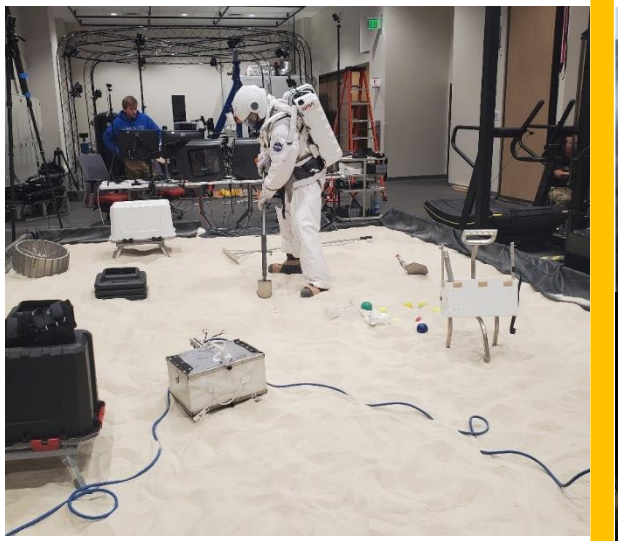


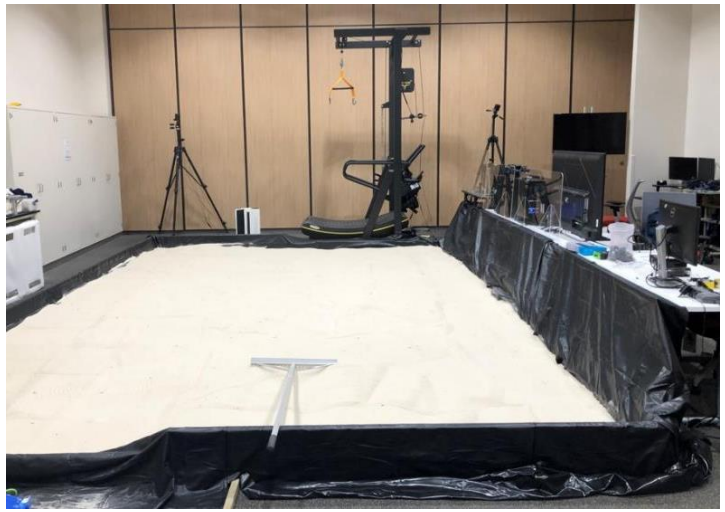
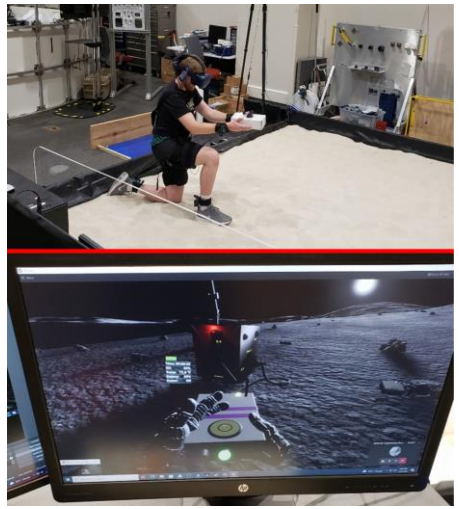
Field Testing

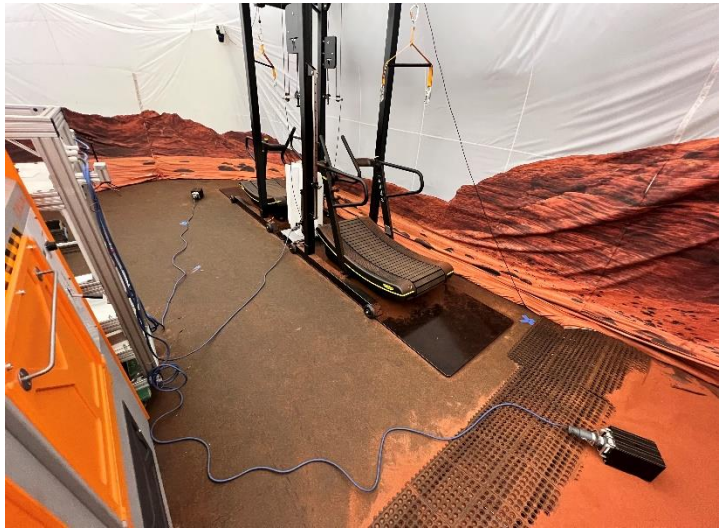
Test Facilities: Hybrid Realities

- The Assessments of Physiology And Cognition in Hybrid-reality Environments (**APACHE**)

- Pro: Great for physical & cognitive evaluation, accessibility, motion capture, and research questions
- Con: lower suited simulation quality, 1g environment, lack of pressurized suit

- Crew Health and Performance Exploration Analog (**CHAPEA**)



Test Facilities

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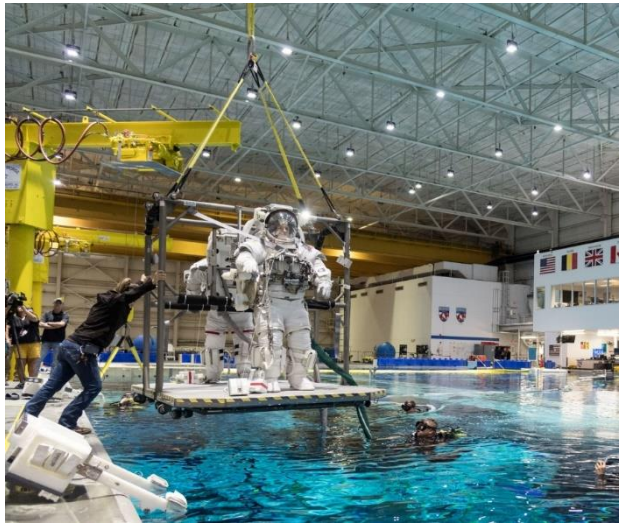

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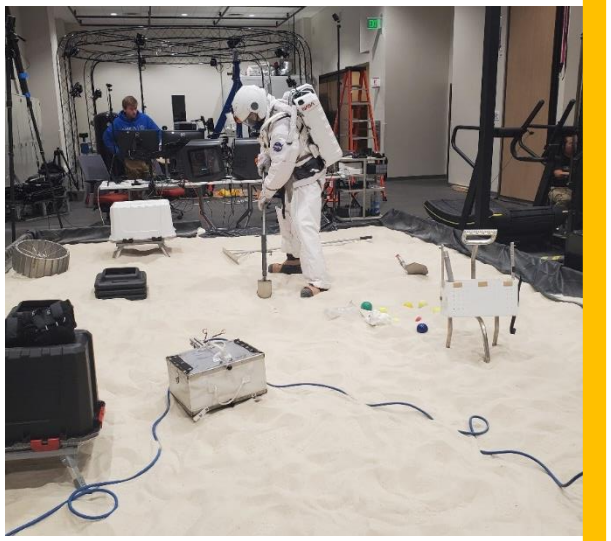
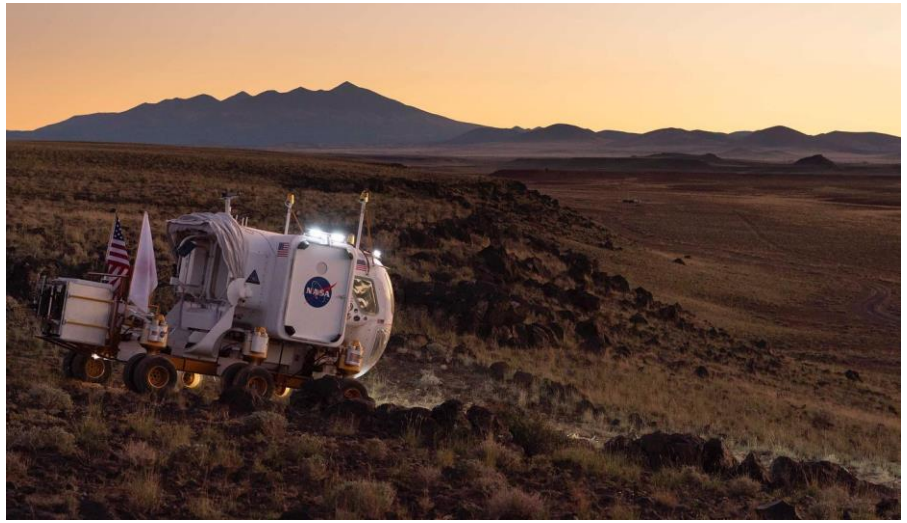


Field Testing

Test Facilities: Field Testing

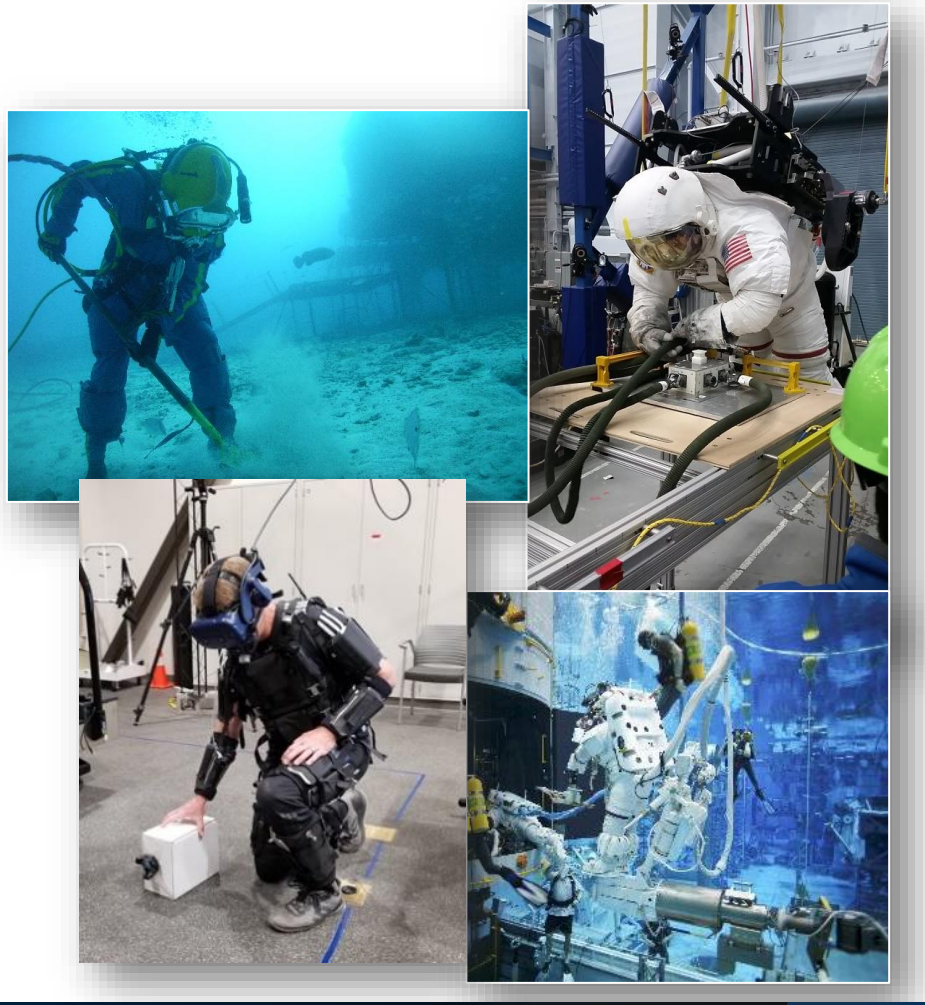
- Pro: Realistic Environment, Geology, EVA-mission simulation
- Con: Uncontrollable variables, 1g environment, communication, limited data collection, lack of pressurized suit



Limitations of Existing EVA Simulation Environments

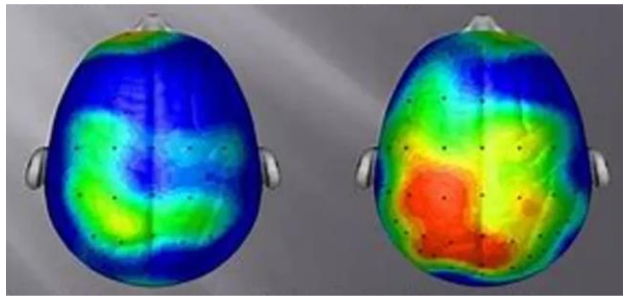
- Typically either physically ***OR*** cognitively realistic
- Limited availability and capabilities
  - Difficult/expensive to integrate physiological sensors
  - Performance measures generally limited and obtrusive
    - *Collecting core temperature data on NBL subjects requires difficult transmission of signals through the human, spacesuit, and water*
    - *Can't wear metabolic analyzers/masks during simulations with primary objectives geared towards communications*
- Learning effects between different suits and environments
- Heavy reliance on small and subjective data sets
- Limited repeatability

- **No one simulation environment is perfect, so it's necessary to conduct research and testing in all of them!**



Physical and Cognitive Workload & Fatigue

- EVAs are both physically and cognitively demanding
- Physical activity can affect cognitive performance and vice versa—both positively and negatively
- Risk estimation, decision making, reaction times, coordination, attention, accuracy, and memory may all be compromised during EVA

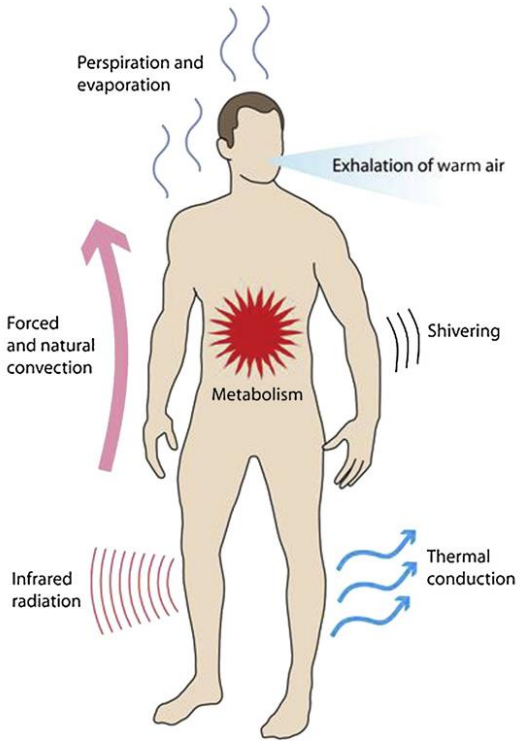


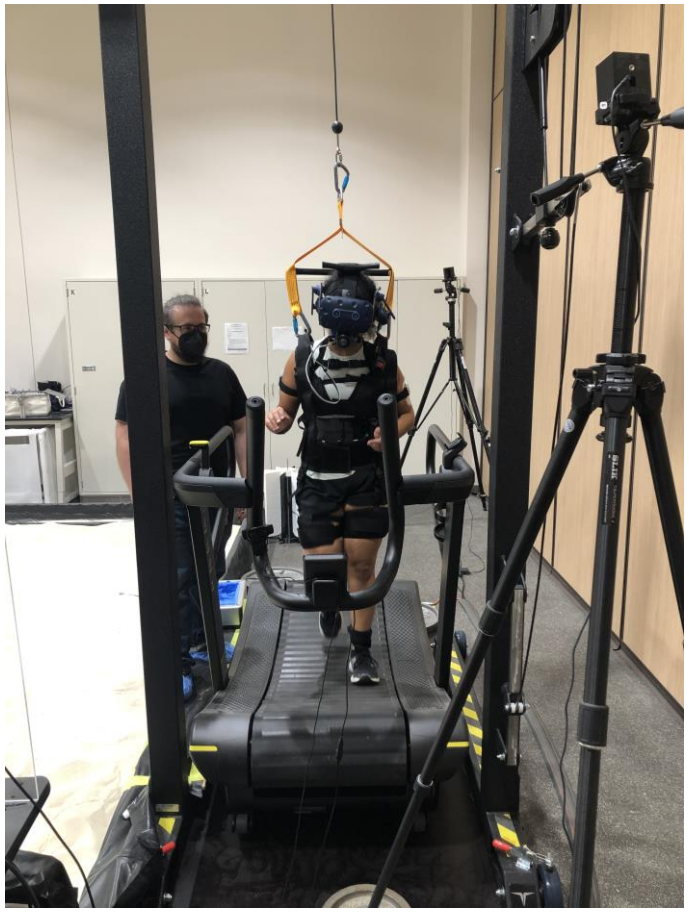
Physically and cognitively realistic test environments are necessary to inform and validate exploration systems and operations

How can we use wearable technology?

- Collect physiological measurements to better understand workload and performance
- Characterize space suit tasks and positions that are difficult for crew members
- Understand the biomechanics of working in a pressurized space suit

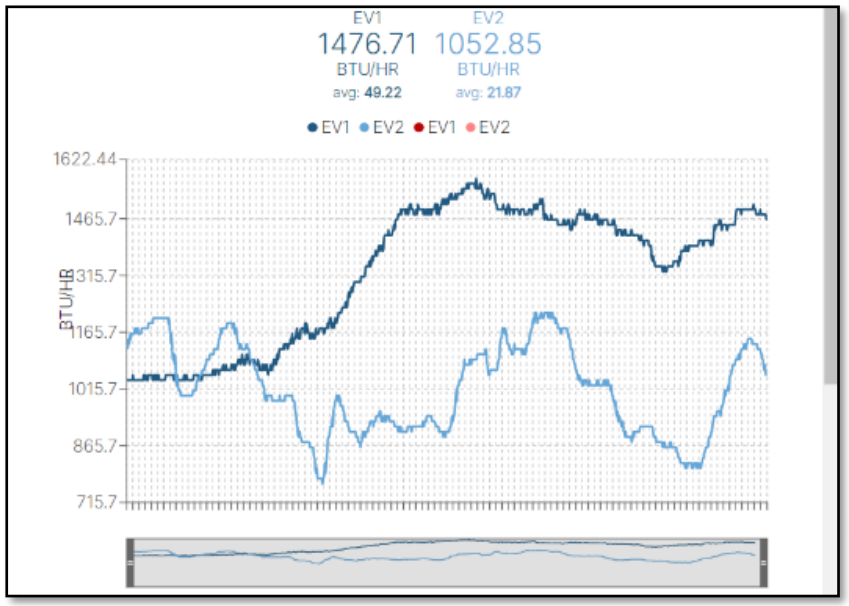
- What physiological data would be relevant to our research?
  - Metabolic rate
  - Heart rate
  - Thermal parameters
  - Kinematics
  - Cognitive workload
  - Hydration, nutrition, and waste management
  - Subjective/qualitative



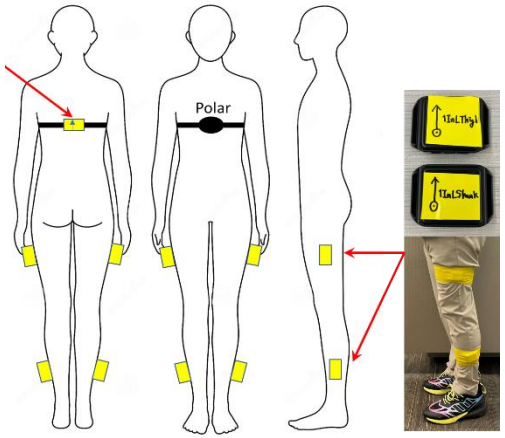


Sensors!

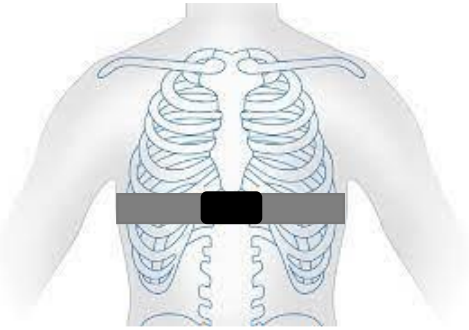
Metabolic Rate

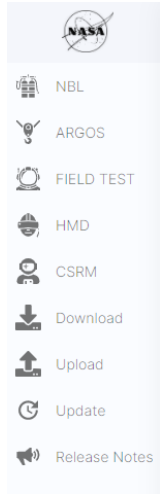


IMUs

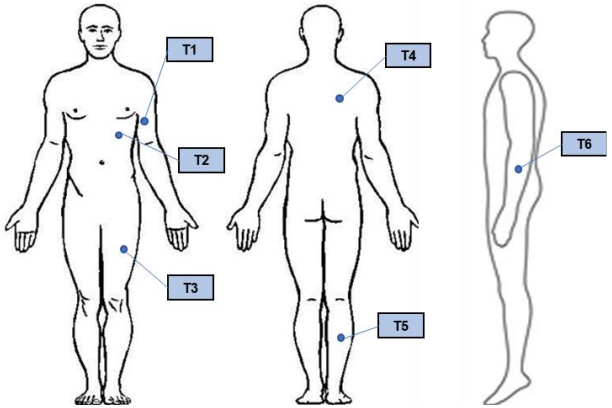


Heart Rate





Thermal Sensors



…and many more!

Past, Current, and Future Efforts

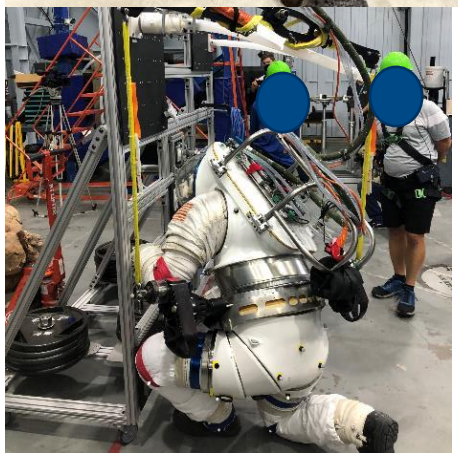
Key Projects

Quick Overviews

Recent ARGOS testing (SSEO/ABF)

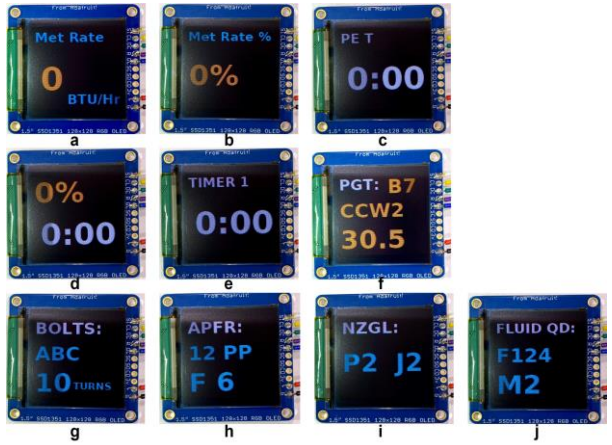
- Lunar Metabolic Rate Study
  - Characterizing metabolic rates during lunar EVA tasks
  - EVA-like timeline & Standalone task timeline
  - Collecting met rate, heart rate, IMU, thermal, subjective rating, cognitive battery data

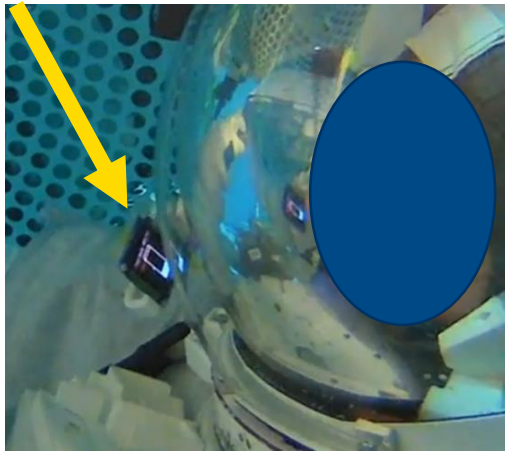
- Egress Fitness
  - First time crew performed an EVA pressurized suit within the first 24 hours after landing
    - Previously not attempted until months after landing
    - Complete series of Martian surface EVA tasks
    - Includes testing at the landing zone to complete a simulated capsule egress
    - Part of the Complement of Integrated Protocols for Human Exploration Research (CIPHER)

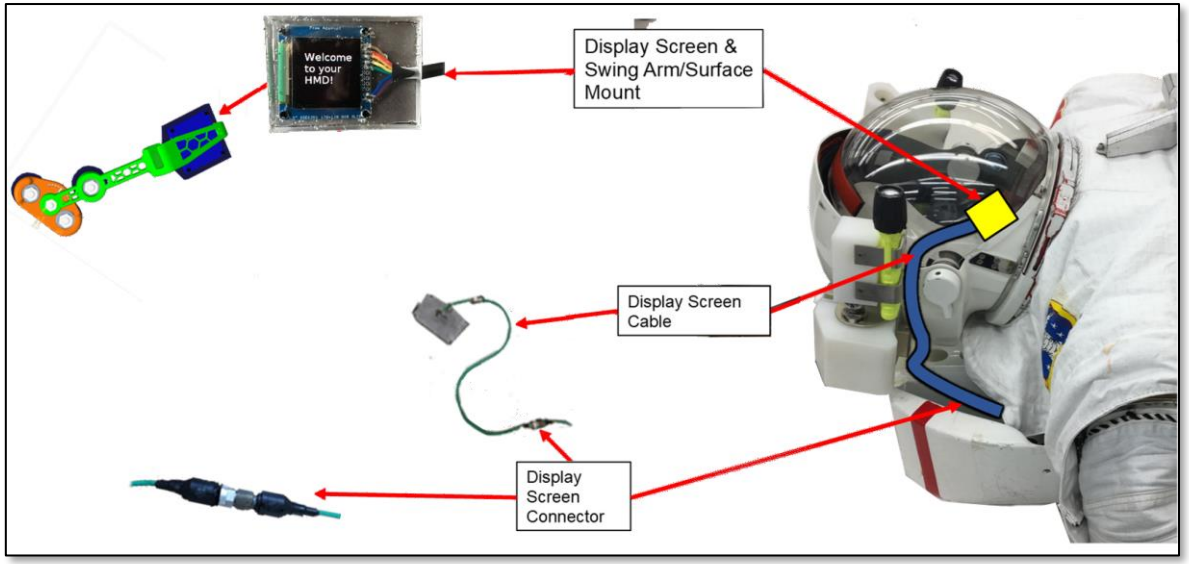


Helmet Mounted Display (SSEO)

- Helmet Mounted Display (HMD)
  - Low-cost, low-tech, rapid development timeline
  - Externally mounted to EMU visor
  - Voice controlled
  - Crew can view real-time met rate, met rate as a percent of their max, PET, HR, and set timers during NBL EVA Training
  - Ability to send instructions/information to EVs via Hippo App and Maestro timeline tracker

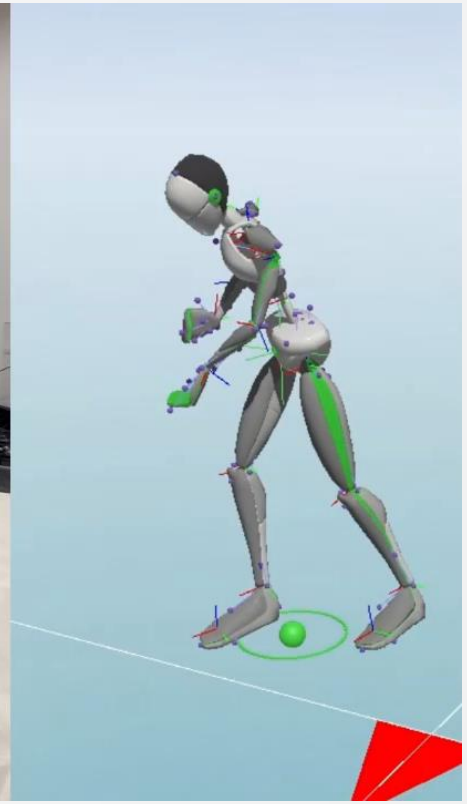






Hybrid Spacesuit Simulator (SSEO)

- Hybrid spacesuit simulator (HS3) was developed as a research tool to add fidelity and realism by way of adjustable physical and cognitive workload



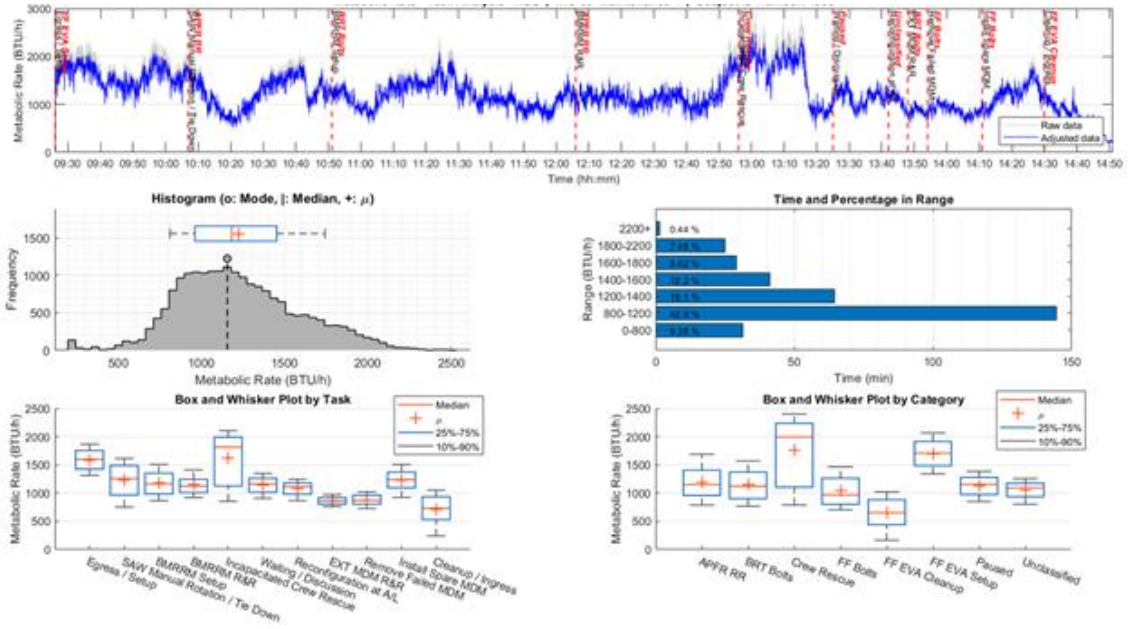
DRATS and JETT3 (FOD/EHP/SSEO)

- Collaboration and integration with other labs and organizations to develop EVA simulation content and embedded performance measures
- Characterize specific tasks with HR and GPS

TARGET ZONE AND INTENSITY % OF HRmax
5 Maximum (90-100%)
4 Hard (80-89%)
3 Moderate (70-79%)
2 Light (60-69%)
1 Very Light (50-59%)

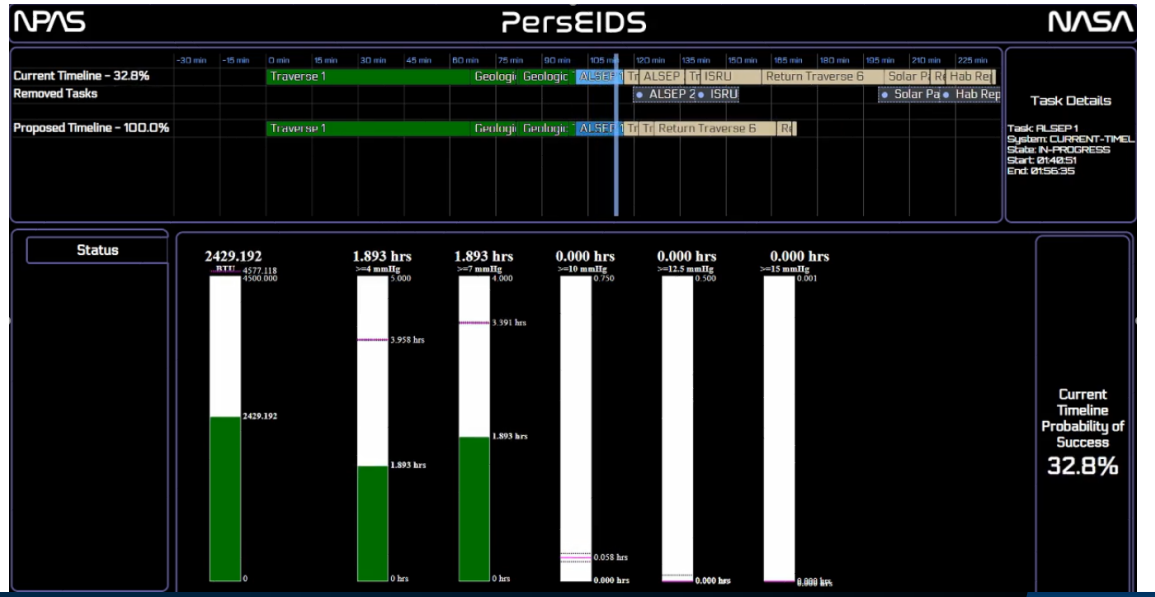
Technology Development (D&S/SSEO)

- **HIPPO App**
  - Software tools for planning, executing, and replanning of EVAs; visualizations and interfaces to support exploration operations;
    and autonomous decision support systems



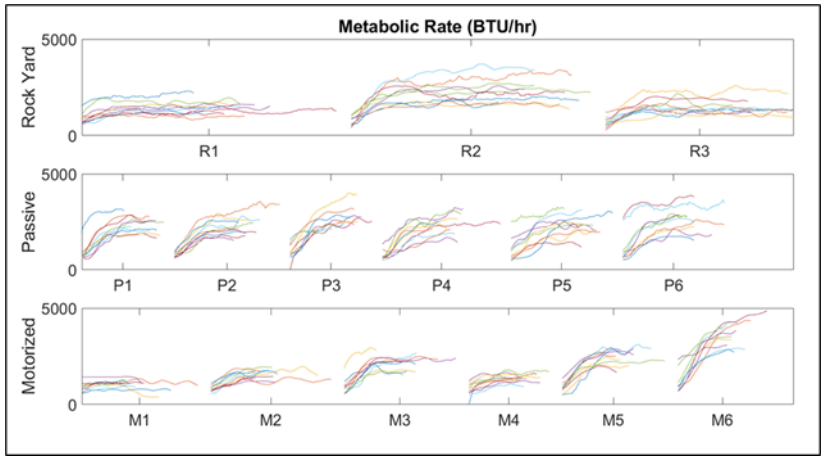
- **Crew State and Risk Model (CSRM)**
  - Develop and validate an integrated set of HHP-relevant models across physiologic and cognitive domains that can accurately infer and predict a crewmember's current and future states

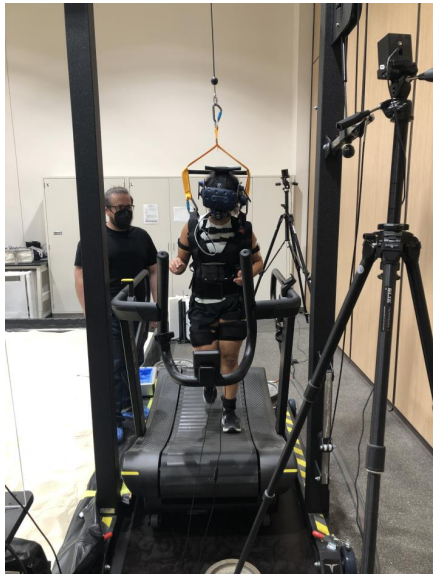
- **PersEIDS**
  - Develop and test a proof-of-concept decision support system to supplement EVAs, IVAs, and console support staff during autonomous exploration EVA simulations



APACHE - VR/XR Testing (SSEO/ER6)

- **Physical Workload Approximation**
  - Treadmill Comparison Study
    - Characterize the voluntary metabolic rate and gait parameters during EVA-like traverses in different analog environments.
    - Results: "…a correction factor is recommended when comparing metabolic costs of ambulating in APACHE with other analog environments because of the inability to significantly change workload via the [passive] treadmill resistance."
- **Cognitive Workload**
  - Psychophysiological Monitoring for Spacewalks
    - Classify cognitive workload using psychophysiological sensing during an operationally-relevant EVA in VR.
    - Results: "During the high workload simulations, participants substantially overused their simulated oxygen resources by walking too fast, identified and recalled more waypoints incorrectly with slower responses, and had more variable reaction times to green indicator lights…"
  - Implementation and Validation of Cognitive Measures in VR/XR (2023)
    - Purpose: Evaluate the ability to measure and collect cognitive workload and physiological data during a simulated science package deployment procedure.





Summary

- Wearable technology allows us to track human performance and better understand EVA capabilities like never before
- **Protecting, enabling, and enhancing the health and performance of crewmembers is vital to the success of NASA's mission**

Thank you!

Questions?